FORM 2

THE PATENTS ACT, 1970
(39 of 1970)
AND
THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(See section 10; rule 13)

TITLE OF THE INVENTION

A LIQUID COOLING AND HEATING GARMENT

APPLICANT

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The following specification particularly
describes the invention and the manner
in which it is to be performed

FIELD OF INVENTION

The present invention relates to a body cooling and heating garment made of biocompatible fabrics and components to provide comfortable body temperature and removal of sweat. Advantageously, the garment has superior heat transfer efficiency and comfort to be conveniently used for maintaining the body temperature of wearer at levels suitable for the physiological performance required.

BACKGROUND OF THE INVENTION

Liquid Cooling and Heating Garments (LCHG) are used in space, military applications, fire fighting and also for personal cooling and heating purpose for protection from hot and cold environment of industrial area or in extreme temperature and humidity conditions that may exist in work environment.These garments typically have a system for circulating temperature controlling fluid into and out of the garments, for instance via tubes positioned in the garment.

In the past, several personal cooling garments have been developed to reduce temperature exposure. Such garments include circulating air systems, ice-cooling devices and circulating fluid systems.

The circulating air system is a one piece impermeable suit with inner air distribution lines and a vortex tube. When connected to supplied air at 80-100 psi, cooled air flows through the suit, removing excess body heat. A major disadvantage of this system is that it requires large amount of air in order to remove heat load. This requires air compressors and hence the capital and running costs are high. Also the vortex tube produces discomfort due to high noise levels and workers are tethered to the air supply via an umbilical cord which restricts mobility.

Ice cooling devices are garments containing small packets of ice which absorb the metabolic heat produced by the human body. The cooling capacity of the ice cooling garment is determined by the amount of ice contained in the garment. The amount of ice is limited to 10-12 pounds for practical purpose. Freezing and storage of the ice

packets requires 8-10 hours approximately by using a high capacity freezer. Once the ice packets are removed from the freezer and placed in the garment, they begin to absorb heat. Therefore, donning the garment must be delayed to the last moment to prevent partial melting of ice and therefore reduction in the cooling capacity of the garment.

Circulated fluid systems utilize a heat sink or reservoir containing water, ice, a pump and a heat exchanger. Cool water is circulated in a closed system through tubes where it absorbs heat and then through the heat exchanger which is in contact with the heat sink. The heat sink is normally worn as a back-pack. Its weight and size impose considerable restrictions upon the wearer, such as the size of the passage way that can be entered. In addition, facilities are required for managing of heat sinks.

U.S.Patent Nos. 5320164 and 5538583 describe a body heating/cooling garment which utilizes fluid carrying tubes and provides both air and vapor permeability to promote convective heat transfer while providing conductive heat transfer also. The garment includes adhesive dots that secure the tubing without interfering with permeability through the garment. However, there has been no consideration made to the compatibility of fabrics, tube and susceptibility of micro organisms. Also, the tubing configuration indicated herein could cause higher pressure drop which may require pump with excess power input.

U.S. Patent No. 4738119 describes a cooling garment for protection against heat stress. The cooling garment includes a pair of separate linings stitched together to form tube receiving chambers on which microporous tubes are detachably connected to a source of liquid carbon dioxide which converts to a solid phase and then gradually sublimates to carbon dioxide gas that is released into the chambers for cooling a wearer. However, the system may not be useful for general purposes and is expensive due to the use of liquid carbon dioxide as cooling medium. Further, the employment of gas as heat transfer medium could lead to inefficiency. The tubing covers only torso and having multiple connections with common manifold may lead to leakage.

U.S. Patent No. 5484448 describes a cooling garment with front and back panels to substantially cover a user's torso with an insulating sleeve in which the cooling pack is retained. However, the cooling garment covers only torso and do not cover the critical areas like shoulder and hip portion where metabolic heat transfer and fluid transfer is more.

It is thus clear that the prior known garments suffer from several drawbacks such as being non-biocompatible and having reduced heat/mass transfer efficiency. The current invention overcomes many of the short falls of the above cited systems.

SUMMARY OF THE INVENTION

In the present invention, a body liquid cooling and heating garment (LCHG) is provided made of biocompatible fabrics and components to provide comfortable body temperature and removal of sweat.

It is an object of the invention to design liquid cooling and heating garment which permits long time usage without any impact on the wearer in terms of skin irritation or infection and is low in cost of manufacture.

Another object of the invention is to improve the heat exchanging efficiency of the suit and robustness of the garment.

Still another object of the invention is to design liquid cooling and heating garment which has a capacity to deal with sweating due to high metabolic rate and convenience in control of heat exchange rate.

It is yet another object of the invention to ensure that the liquid cooling and heating garment is self supporting, easy to construct and confers excellent heat transfer efficiency.

The liquid cooling and heating garment in accordance with the present invention finds applications in human space flight and also for earth bound operations such as fire fighting, working in steel mill etc.

According to one aspect of the invention there is provided a liquid cooling and heating garment for controlling body temperature of the wearer comprising (a) an outer layer forming the outersurface of the garment made of polymeric fabric net (b) an inner layer of polymeric fabric tricot in contact with the skin of the wearer wherein the outer and inner layers of the garment are separated there between by a plurality of tubes configured to circulate a heat transfer fluid across desired areas of the body of the wearer through atleast one inlet and atleast one outlet operably connected to a suitable valve means to selectively control the supply of the heat transfer fluid to and from the heat transfer reservoir.

Further scope and applicability of the present invention will become apparent from the detailed description given hereafter. However, it should be understood that the detailed description and specific examples, while indicating embodiments of the invention, are given by way of illustration only, because various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be described in detail with reference to the embodiments shown diagrammatically in the drawings and data in tables wherein:

Figure 1: Schematic of the 3 layer configuration of LCHG

Figure 2: Schematic of tube configuration in LCHG

Figure 3: Representation of the finite element model

Figure 4: LCHG specimen configuration for testing

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of the embodiments, reference is made to drawings that form a part hereof, and in which are shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and processing step/structural changes may be made without departing from the scope of the present invention.

The present invention provides a thermodynamically efficient liquid cooling and heating garment for cooling and/or heating the body of the wearer. Also described herein is a method for fabrication of the garment made of biocompatible fabrics and parts to provide comfortable body temperature and removal of sweat.

The liquid cooling and heating garment (LCHG) in accordance with the present invention is a close fitting long garment, covering the body torso and limbs from neck to toe. This is an independent, single piece, lightweight comfort inner wear with front entry zipper made of biocompatible polymer.

The liquid cooling and heating garment (LCHG) of the present invention is a tri-component fabric system.

The present invention in accordance pertains to a liquid cooling and heating garment for controlling body temperature of the wearer comprising (a) an outer layer forming the outersurface of the garment made of polymeric fabric net (b) an inner layer of polymeric fabric tricot in contact with the skin of the wearer wherein the outer and inner layers of the garment are separated there between by a plurality of tubes configured to circulate a heat transfer fluid across desired areas of the body of the wearer through atleast one inlet and atleast one outlet operably connected to a suitable valve means to selectively control the supply of the heat transfer fluid to and from the heat transfer reservoir.

According to an embodiment of the invention, the outer and inner layers are made of biocompatible material and coated with an anti-microbial agent.

According to a preferred aspect of the invention, the tubes are tied to the polymeric fabric net by a polymeric thread.

Another aspect of the disclosure pertains to a method of fabricating a garment for controlling body temperature of the wearer comprising (a) an outer layer forming the outersurface of the garment made of polymeric fabric net (b) an inner layer of polymeric fabric tricot in contact with the skin of the wearer wherein the outer and inner layers of the garment are separated there between by a plurality of tubes configured to circulate a heat transfer fluid across desired areas of the body of the wearer through atleast one inlet and atleast one outlet operably connected to a suitable valve means to selectively control the supply of the heat transfer fluid to and from the heat transfer reservoir.

Referring now to FIG. 1, there is shown the three-layer configuration of the LCHG comprising an inner layer, tubes and outer layer.

FIG. 3 is a diagram showing the three-layer configuration in accordance with the finite element model. As illustrated in the configuration depicted in FIG. 3, the inner most layer (3) is a soft sweat absorbing layer made of polymeric-tricot fabric which remains in thermal contact with the skin of the wearer. The highly flexible polymeric-tricot fabric has sufficient mechanical strength and is biocompatible. An antibacterial coating facilitates long time wearing of the garment without any skin irritation, infection and microbial contamination. The polymeric fabric tricot conforming to the surface of the skin has a one way wicking property and removes the sweat away from the body.

As shown in FIG. 3, the outermost layer (1) of the LCHG is a polymeric fabric net supporting and integrally holding the network of heat transfer tubes (2) arranged in

many sections of parallel arrays by suitable holding means. The polymeric fabric net is also biocompatible and ensures good ventilation. The inner layer (3) and outer layer (1) of the LCHG together maintain the shape and dimensional stability of the garment.

Sandwiched between the inner polymeric-tricot layer (3) and the outer polymeric fabric net layer are flexible tubes through which the heat exchanging fluid is passed. According to one aspect, the polymeric tube is tied to the polymeric fabric net by a polymeric thread. The tubing can be divided up into specific zones, such that the area that is being cooled or heated can be controlled. The tubes are biocompatible or medical grade plasticizer free flexible polymer tubes having higher thermal conductivity, higher mechanical strength with antimicrobial coating. The coolant used for the liquid cooling garment is chilled water.

The biocompatible polymeric fabric layers sandwiching flexible tubes for heat transfer fluid comprise looped heat transfer tubes forming many sections of parallel arrays permitting passage of fluid freely through them with the feed and return connected to tubing manifold for connections to an external source through Quick Connection and Disconnection (QCDC) joints to heating and cooling fluid.

The tubing is configured in a manner that at least one inlet of the tube is connected to an inlet manifold and atleast one outlet of the tube is connected to an outlet manifold by Quick Connect and Disconnect Couplings (QCDC).

The materials chosen for the purpose can be of polyester, polyurethane or any polymeric fabric and tubing which could meet the requirements as specified in Table-1.

Table-1 Selection criteria of materials for LCHG

Material	Functional requirements/Selection criteria
Inner layer	Wicking layer, sweat absorption, flexibility, high permeability and biocompatibility, light weight, low grams per square meter (GSM), low Total Mass Loss (TML), low Collected Volatile Condensable Materials (CVCM) with antibacterial coating
Tubes	Coolant tubes-Flexibility and low hardness, high thermal conductivity, low density, plasticizer free and biocompatibility, low GSM, low TML, CVCM with antibacterial coating
Outer layer	Ventilation Layer-flexibility, support for tubes and openings for ventilation, low GSM, low TML, CVCM and biocompatible

FIG. 2 depicts a schematic representation of the tube configuration in the LCHG on the body of the wearer covered with the heat exchanging garment of the present invention.

The water transport tube will have two Quick Connection and Disconnection (QCDC) couplings "QCDC M, QCDC N" attached to both ends. These couplings are connected to the corresponding water inlet and outlet tubing arrangement of heat transfer fluid reservoir. For temperature control, chilled water in the temperature range of 5-25 °C (for cooling) or hot water in the temperature range of 30-50 °C (for heating) is circulated. The flow rate of the heat transfer fluid is preferably in the range of 50 ml/min – 1000 ml/min.

The prefered values for various parameters of the Liquid cooling and heating garment is tabulated in table 2 below. It has been suprisingly identified that the parameters as depicted below for various components of the garment offer optimum heat transfer efficiency contributing to the robustness of the system.

Table-2 Preferred parameters for the LCHG

Si No.	Parameter	Desirable Values
1	Total tube length	60-90 m
2	Tube size	ID = 2-5 mm OD = 4-7 mm
3	Distance between two parallel tubes	1.5 – 3 cm
4	Number of critical bends (2-4 cm curvature)	30 (max.)
5	Heat transfer fluid flow (water) rate	50 -1000 ml/min
6	Pressure drop	0.1-1.0 bar
7	Coolant inlet, outlet temperatures	10-15 °C, 25-30 °C
8	LCHG total weight	1000-3000 g

A preferred configuration of the tubing is described herein. Every componet and part of the garment is numbered. As illustrated in FIG. 2, the tube routing starts from outlet of manifold-A (QCDC a), passing through right hand armpit and covers shoulder portion (region 1 and 2), torso on right side (region 3), thigh (region 4 and 5), hip (region 6) portion and it passes through the back side of torso right side (region 7) and then covers shoulder and torso and to the leg portion (region 8 and 9). The routing covers half of the body and then ends up at QCDC h. Similarly left side is routed and the routing follows region 10 to 18. Both ends are connected to manifold - B with quick connect and disconnect (QCDC) connectors. If cooling is not required on legs, these routings could be disconnected at connecters "d, e, f, g" and the connecter "d" can be connected to "e", connecter "f" can be connected to "g". Apart from this, a tube routing from manifold-A (QCDC c) starting from right hand side (region 19) shall cover entire hand (region 19, 20), head (region 21) portion and the left hand portion (region 22, 23) finally ending up at manifold-B (QCDC j). This configuration having three inlets at manifold-A and three outlets at manifold-B with a total of 12

QCDC connectors (a to j) out of which four are used to connect routing from torso to leg inlets and outlets (d, e, f and g as shown in figure-2).

HEAT AND MASS TRANSFER EXPERIMENTS

The heat transfer efficeincy of the three layer LCHG system was evaluated experimentally. A specimen of three layer system as shown in Figure-4 was employed. The heat input to the system, flow rate of coolant, fluid transport through fabrics were simulated. The surface temperature of the inner layer was monitored. The air temperature and velocity over the garments was also simulated. Heat transfer effectiveness of the system for coolant flow rate of 100 ml/minute was obtained. Effectiveness of the LCHG system for total heat dissipation was proven by the experiments.

LCHG BASIC DESIGN PARAMETERS

Data generated through finite element model and heat transfer experiments were utilized for optimal design of the LCHG. The design parameters for LCHG are suitable for persons having body mass index (BMI) as 19 – 27 with surface area of body as 1.45 – 2.15 m^2 is given in Table-2.

We claim:

1. A garment for controlling body temperature of the wearer comprising (a) an outer layer forming the outersurface of the garment made of polymeric fabric net (b) an inner layer of polymeric fabric tricot in contact with the skin of the wearer wherein the outer and inner layers of the garment are separated there between by a plurality of tubes configured to circulate a heat transfer fluid across desired areas of the body of the wearer through atleast one inlet and atleast one outlet operably connected to a suitable valve means to selectively control the supply of the heat transfer fluid to and from the heat transfer fluid reservoir.
2. The garment as claimed in claim 1, wherein the garment is a tri-component fabric system.

3. The garment as claimed in claim 1, wherein the outer and inner layers are made of biocompatible material and coated with an anti-microbial agent.

4. The garment as claimed in claim 1, wherein the tubes are tied to the polymeric fabric net by a polymeric thread.

5. The garment as claimed in claim 1, wherein, at least one inlet of the tube is connected to an inlet manifold and atleast one outlet of the tube is connected to an outlet manifold by Quick Connect and Disconnect Couplings (QCDC).

6. The garment as claimed in claim 1, wherein the tube is a polymeric tubes and plasticizer free.

7. The garment as claimed in claim 1, wherein the total tube length is 60-90 m.

8. The garment as claimed in claim 1, wherein the tubes are arranged in sections of parallel arrays.

9. The garment as claimed in claim 1, wherein the distance between two parallel tubes is 1.5 to 3cm.

10. The garment as claimed in claim 1, wherein the heat transfer fluid is water.

11. The garment as claimed in claim 9, wherein the cooling is achieved by circulating chilled water in the temperature range of 5-25°C and heating is achieved by circulating hot water in the temperature range of 30-50°C.

12. The garment as claimed in claim 1, wherein the heat transfer fluid flow rate is 50 – 1000 ml/min.

13. The garment as claimed in claim 1, wherein the pressure drop of the heat transfer fluid flow rate is 0.1 – 1.0 bar.

14. The garment as claimed in claim 1, wherein the total weight of the garment is 1000-3000g.

15. A method of fabricating a garment for controlling body temperature of the wearer comprising (a) an outer layer forming the outer surface of the garment made of polymeric fabric net (b) an inner layer of polymeric fabric tricot in contact with the skin of the wearer wherein the outer and inner layers of the garment are separated there between by a plurality of tubes configured to circulate a heat transfer fluid across desired areas of the body of the wearer through atleast one inlet and atleast one outlet operably connected to a suitable valve means to selectively control the supply of the heat transfer fluid to and from the heat transfer fluid reservoir.

16. The method as claimed in claim 15, wherein at least one inlet of the tube is connected to an inlet manifold and atleast one outlet of the tube is connected to an outlet manifold by Quick Connect and Disconnect Couplings (QCDC).

17. The method as claimed in claim 14, wherein the cooling is achieved by circulating chilled water in the temperature range of 5-25°C and heating is achieved by circulating hot water in the temperature range of 30-50°C.

18. The garment as claimed in claim 1, wherein the heat transfer fluid flow rate is 50 – 1000 ml/min.

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ABSTRACT

The present invention relates to a liquid cooling and heating garment made of biocompatible fabrics and parts to provide comfortable body temperature and removal of sweat. Advantageously, the garment has superior heat transfer efficiency and can be conveniently used for maintaining the body temperature of wearer at levels suitable for the physiological performance required.These garments find use in human space flight and also for earth bound operations such as fire fighting, working in steel mill and the like.